Resource Action: EWG-37	**Task Force Recommendation Category: 2**

Operate the Oroville Facilities to Provide Additional Cold Water in the High Flow Channel of the Feather River for Benefit of Chinook Salmon and Steelhead

Related Resource Actions:

- EWG-27, which proposes to fill, modify, or isolate Robinson Riffle Borrow Pit.
- EWG-35A & EWG-35B, which propose to reduce rates of fish predation on juvenile salmonids by reducing water temperatures.
- EWG-36, which proposes to operate the Oroville Facilities in a manner that would provide colder water in low flow channel of the Feather River for benefit of Chinook salmon and steelhead.
- EWG-87, which proposes to modify the Thermalito Complex facilities in a manner to increase water temperatures in the Thermalito Afterbay and reduce temperatures in the Feather River downstream of the Afterbay outlet for beneficial uses.
- EWG-102, which proposes to provide water temperatures in the lower Feather River that mimic historic (pre Oroville Dam) to help maintain the genetic integrity of the spring-run Chinook salmon.

Date of Field Evaluation: No field evaluation was conducted

Evaluation Team: Phil Unger and David Sun

Description of Potential Resource Action Measure:
This measure would include structural changes and/or changes in operations of the Oroville Facilities to reduce water temperatures in the High Flow Channel of the Feather River (HFC) during certain times of year for the benefit of Chinook salmon and steelhead. The changes in operation would likely include releasing colder water from the reservoir and increasing releases to the Low Flow Channel (LFC). Proposed structural changes include constructing a canal to transport cold water directly from the Thermalito Pumping-Generating Plant tail channel to the southeastern portion of the Thermalito Afterbay, near the river outlet, thereby reducing the residence time of water in the Afterbay and reducing temperature of the water released into the river.

Nexus to the Project:
Water temperatures in much of the lower Feather River are strongly affected by operations of the Oroville Facilities. The Oroville Facilities allow project operators to regulate the depth in Oroville Reservoir from which water is released, the amount of water released from the reservoir into the river, the amount of water diverted from the LFC of the river through the Thermalito Complex, and the amount of water pumped back into the reservoir from the Thermalito Complex. These operational controls give

the operators various degrees of control over water temperatures in the LFC and the upper reaches of the HFC.

The 1983 agreement between the California Department of Water Resources (DWR) and California Department of Fish and Game (DFG), concerning the operation of the Oroville Division of the State Water Project for management of fish and game, established quantitative water temperature criteria for the lower Feather River. In this agreement, the Oroville Project is required to meet quantitative water temperature criteria at two downstream locations: the Feather River Hatchery (FRH) and the LFC at Robinson's Riffle (River Mile 61.6).

The water temperature criteria at the FRH and Robinson's Riffle are the principal water temperature targets controlling Oroville Project operations, but other water temperature objectives and goals occasionally influence project operations and potentially affect water temperatures in the HFC. The 1983 agreement established a narrative water temperature objective for the Feather River downstream of the Thermalito Afterbay outlet. This objective requires water temperatures downstream of the Thermalito Afterbay outlet that are suitable for fall-run Chinook salmon during the fall (after September 15) and suitable for shad, striped bass and other warmwater species from May through August. This narrative has no direct effect on operations because it is not well defined, but it has encouraged operators to seek opportunities to provide colder water to the HFC during the fall months.

An informal water temperature goal of the Oroville Facilities operators exists for the Thermalito Afterbay. This goal recognizes the need of local rice farmers for warm water temperatures during spring and summer for germination and growth of rice. Most of the rice farmers divert their irrigation water from the Thermalito Afterbay. Water temperature goals to support rice production are a minimum of 65°F during April through mid-May and a minimum of 59°F for the remainder of the growing season. Although DWR is not obligated to meet these goals, Project operators try to accommodate the rice farmers by releasing water as close as possible to the maximum temperature allowed under the FRH criteria. Because most of the water in the Thermalito Afterbay ultimately spills into the HFC of the Feather River, increases in Thermalito Afterbay water temperatures likely produce higher HFC water temperatures.

A recent evaluation conducted by the EWG fisheries technical team of Chinook salmon and steelhead water temperature needs in the Feather River suggests that under current Oroville Project operations, the water temperatures in the HFC of the Feather River are seasonally too warm for salmon and steelhead holding, spawning and rearing. Releases of water into the Feather River from the Thermalito Afterbay contribute substantially to the elevated water temperatures of the HFC.

Potential Environmental Benefits:
Based on recent water temperature conditions and the life histories of spring-run Chinook salmon and steelhead, this Resource Action would be most effective if implemented from April through October. This period includes the rearing period for spring-run Chinook salmon and steelhead and the immigration, holding and spawning period for spring-run and fall-run Chinook salmon.

The EWG fisheries team determined Chinook salmon and steelhead water temperature needs for each life-stage by synthesizing information obtained from the fisheries literature. Both fall-run and spring-run Chinook salmon spawn in the LFC beginning in early September. The upper reaches of the HFC have an abundance of suitable spawning gravels, but limited spawning occurs in the HFC because water temperatures are generally too warm. The EWG team determined that spawning and egg incubation water temperature requirements for Chinook salmon are no more than 56°F or 58°F (the two values reflect minor differences in the set of literature sources used for deriving the critical temperature estimates) (Table 1). Steelhead begin spawning about December, but continue spawning until approximately April, and egg incubation can continue through May. The EWG team determined that spawning and egg incubation temperature requirements for steelhead are 52°F and 54°F (again, the two values reflect differences in the set of literature sources used for estimates). Spring run adults hold in pools in the LFC from late spring through summer and fall run migrate upstream in late summer and hold more briefly. The EWG team determined that upstream migration and holding temperature requirements for adult spring-run and fall-run Chinook salmon are 60°F and 64°F (as before, the two values reflect differences in the set of literature sources used for estimates).

Life stage Activity/ Species or Run	Period	Upper Water Temperature Limit*
Spawning and Egg Incubation		
Spring-run Chinook	September – mid February	56°F & 58°F
Fall-run Chinook	September – mid February	56°F & 58°F
Steelhead	December - May	52°F & 54°F
Immigration and Holding		
Spring-run Chinook	March - October	60°F & 64°F
Fall-run Chinook	mid July - December	60°F & 64°F
Steelhead	September – mid April	52°F & 56°F

* Two values reflect minor differences in literature sources used to derive temperature limits.

Table 1. Months and Temperature Limits of Chinook Salmon and Steelhead Lifestages.

The suitability of water temperature conditions for Feather River salmon and steelhead was evaluated by comparing the water temperature limits in Table 1 to results of benchmark study water temperature modeling runs of existing (2001) conditions. The benchmark study simulates water temperatures at different locations based on current level-of-development hydrology and the current regulatory framework. The study estimates natural variability by using the 1922 through 1994 water year hydrology and meteorology for the water temperature simulations. Figures 1 through 3 present results of the study for two locations in the LFC: one location is 0.4 river miles upstream of the Thermalito Afterbay river outlet and the other is 13.1 river miles downstream of the outlet and just upstream of the Honcut Creek confluence. The Thermalito Afterbay outlet marks the upstream limit of the HFC. The analysis of water temperatures is limited to the HFC upstream of Honcut Creek because this portion of the HFC has the best spawning habitat conditions and because, realistically, modifications to the Oroville Facilities or their operations would be unable to affect water temperature further downstream. Figure 1 shows typical and extreme water temperatures for each location and month, as represented by the median of the daily average water temperatures, the 95th percentile of the daily maximum water temperatures and the 5th percentile of the daily minimum water temperatures. The figure also shows the most critical upper water temperature limits for each month, as described below. The results show that in all seven months, the median water temperature increases downstream from the Thermalito Afterbay outlet. Also, the median water temperatures at both HFC locations increase from April through August, and then decline. Figures 2 and 3 provide exceedance plots for daily average water temperatures in April through November at the two HFC locations.

Table 2 gives the frequencies, as percentages, that the salmon and steelhead water temperature limits are exceeded for each month from April through November at each of the HFC locations. These results are based on the temperature limits in Table 1 and the exceedance data in Figures 2 and 3. For each month from April through November, Table 2 gives the species/life history stage activity with the most restrictive (coldest) water temperature limits, the two water temperature estimates of those limits from Table 1, and the percentage of days during each month that the daily average water temperature exceeds each limit. These percentages are provided for the two locations in the HFC; downstream of the Thermalito Afterbay river outlet and upstream of Honcut Creek. For September, October and November, the temperature limits and exceedance frequencies are provided for two species/life stage activities, spring-run and fall-run salmon spawning and egg incubation and steelhead immigration and holding. Although steelhead immigration and holding has colder water temperature requirements than salmon spawning and egg incubation, the latter are considered to be more critical because of the greater sensitivity of spawning and egg incubation to unsuitable water temperature conditions.

Month	Limiting Species/Life Stage*	Upper Temperature Limits (°F)**	Frequency of Exceeding Limits (%)	
			Below TAO	Above Honcut
April	SH S&E	52 and 54	87 and 53	95 and 84
May	SH S&E	52 and 54	97 and 88	99 and 96
June	SR I&H	60 and 64	63 and 16	93 and 53
July	SR & FR I&H	60 and 64	84 and 31	98 and 70
August	SR & FR I&H	60 and 64	99 and 63	100 and 94
September	SR & FR S&E; SH I&H	56 and 58; 52 and 56	100 and 97; 100 and 100	100 and 100; 100 and 100
October	SR & FR S&E; SH I&H	56 and 58; 52 and 56	90 and 68; 98 and 90	100 and 85; 100 and 96
November	SR & FR S&E; SH I&H	56 and 58; 52 and 56	50 and 23; 75 and 50	90 and 42; 90 and 61

* SH=steelhead, SR=spring-run chinook, FR=fall-run chinook, S&E=spawning and egg incubation, I&H=immigration and holding
** Two values reflect minor differences in literature sources used to derive temperature limits.

Table 2. Frequencies of Exceeding Temperature Limits of Limiting Species/Life Stage during each Month based on Benchmark Study Simulation Results

With few exceptions, the results in Table 2 show that the temperature limits are usually exceeded in every month at both locations in the HFC. The lower temperature limit for Chinook salmon immigration and holding is exceeded less than half of the days in June and July at the location just downstream of the Thermalito Afterbay outlet, and the lower temperature limit for salmon spawning and egg incubation is exceeded less than half of the days in November at both HFC locations.   However, in all other months and locations, the temperature limits are exceeded at least half of the time, and in many months and locations they are exceeded more than 90 percent of the time.

It should be noted that the frequencies of occurrence are not equivalent to probabilities because water temperatures on a given day are not independent events, but rather tend to be related to temperatures on neighboring dates. As a result, water temperatures of a month within a year tend to be more similar than those of the same month in other years. This is significant because it means that the probability of exceeding a temperature limit every year is actually somewhat lower than suggested by the frequencies in Table 2. Nevertheless, the results clearly indicate that reducing water temperatures in the HFC would benefit salmon and steelhead. As shown in Figure 1, the median water temperatures at the HFC locations substantially exceed the temperature limits in many of the months, indicating that fairly large reductions in water temperatures are needed.

Potential Constraints:
As previously noted, this Resource Action would likely include releasing colder water from Oroville Reservoir and/or increasing flow releases to the LFC. However, several important potential constraints could limit these changes in operations.

A major potential constraint is the need to maintain current Oroville Project contributions to the statewide water supply. The Oroville Project is one of many water projects coordinated to meet California's water supply needs. Releases from the different storage reservoirs of the State Water Project and Central Valley Project are carefully managed in a coordinated fashion to satisfy irrigation, municipal and environmental demands without unduly risking future supplies. The amount of water released from Oroville Reservoir cannot be substantially altered without disrupting this system. Increasing Oroville Project deliveries at one time would generally require reductions in deliveries at other times, and such reductions could be mitigated only by requiring other water projects to increase their deliveries or by reducing demand. The Oroville Project cannot reduce demand or alter the delivery schedules of other water projects. If the total releases from the Oroville Facilities cannot be changed, water temperatures in the HFC can be reduced only by varying the proportion of flow reaching the HFC that passes through the LFC versus the Thermalito Complex, by releasing colder water from the reservoir, or by structural modifications of the Thermalito Afterbay.

Substantially increasing the proportion of flow directed through the LFC is constrained by habitat considerations. Instream flow studies of fish habitat (PHABSIM) indicate that the availability of spawning habitat for chinook salmon and steelhead in the LFC are maximized at a flow of about 800 cfs. Therefore, HFC water temperature benefits potentially gained by increasing LFC flow above 800 cfs could be offset by LFC reductions in habitat availability.

Another major constraint on this Resource Action is the limited volume of Oroville Reservoir's cold-water pool. The limited volume of cold water in the reservoir restricts how much and for how long water temperatures in the HFC could be reduced. This constraint would be particularly significant in dry and critically dry water type years. Also, releasing very cold water would adversely affect egg development and growth of juvenile salmonids in the LFC and the FRH. Note that the FRH water temperature criteria limit the amount of reduction in water temperatures that are allowed to be released from Lake Oroville.

Another important constraint is the loss of power generation through the hydroelectric facilities that would potentially accompany implementation of this measure. Operations that can be used to reduce water temperatures in the HFC include increasing flow releases to the LFC, reducing pump-back and peaking operations, and opening the Oroville Dam river valve (the least desirable option). These actions would typically result in varying degrees of losses in hydroelectric power generation.

This measure could also be constrained by regulatory requirements. A narrative objective for water temperatures in the Feather River below the Thermalito Afterbay river outlet requires water temperatures that are suitable for shad, striped bass and other warmwater species from May through August. Reducing spring and summer water temperatures in the HFC could make it difficult to meet this objective. Measures to reduce water temperatures in the HFC are also potentially constrained by the goal to supply rice farmers with warm water during spring and summer and by the goal to provide suitable warm water for recreation activities.

Existing Conditions in the Proposed Resource Action Implementation Area:
The portion of the lower Feather River that is the focus of this Resource Action is the upstream section of the HFC, extending about 14 miles from the Thermalito Afterbay outlet to Honcut Creek. The minimum flows and the water temperature targets in the HFC are established by a 1983 agreement between DWR and DFG. The instream flow requirements are 1,700 cfs from October through March and 1,000 cfs from April through September for wetter years (> 55% of normal runoff), and 1,200 cfs for October through February and 1,000 cfs for March through September for drier years. As previously described, the water temperature must be suitable for fall-run Chinook salmon after September 15, and they must be suitable for shad, striped bass, and other warmwater species, from May through August.

Spring and summer water temperatures in the HFC are typically warmer than those in the LFC in large part because of the large volumes of relatively warm water released to the HFC from the Thermalito Afterbay outlet. Water temperatures in the Thermalito Afterbay are relatively high because water moves more slowly through the Thermalito Complex, and especially the Afterbay, than through the LFC and is subject to greater atmospheric warming. The contribution of the Thermalito Afterbay outlet inflow to the total flow of the HFC is typically greater than that of the LFC flow.

The releases of large flows with relatively high water temperatures from the Thermalito Afterbay outlet typically results in a sharp thermal gradient from the downstream end of the LFC to the upstream end of the HFC. Water temperatures in the HFC just downstream of the Afterbay outlet are often several degrees warmer than temperatures in the lower part of the LFC (upstream of Thermalito Afterbay outlet), particularly in the late spring and early autumn.
Beyond the influence of the Thermalito Afterbay outlet, downstream warming in the HFC is relatively low, at least as compared to that in the LFC. Figure 4 shows rates of warming in the HFC, the LFC, and the transition between the LFC and HFC. The rates are expressed as increases in temperature per river mile. The Figure shows warming for one reach in the HFC, from the location 0.4 river miles downstream of the Afterbay outlet to that just upstream of Honcut Creek (12.7 river miles), and for two reaches in the LFC, from the Fish Barrier Dam to Robinson's Riffle (5.55 river miles), and from Robinson's Riffle to a site 0.4 miles upstream of the Thermalito Afterbay outlet (2.3 river miles). The transition reach is from the site upstream of the Afterbay outlet to that

downstream of the outlet (0.8 river miles). Figure 4 shows that rates of warming are relatively low and quite consistent from April through October in the HFC. Warming rates are generally higher in the LFC reaches, especially in the summer months. The reduced warming rate in the HFC is attributable to its higher flows and to the fact that the HFC water temperatures are usually more nearly in equilibrium with atmospheric temperatures than the LFC water temperatures. Rates of warming in the transition reach are often very high and highly variable because of the effect of the Thermalito Afterbay releases. These rates are especially high in spring and fall. In July, however, the warming rate in this reach is almost as low as that in the HFC.

Design Considerations and Evaluation:
As previously indicated, some measures to significantly reduce water temperatures in the HFC would potentially affect habitat conditions in the LFC adversely.

Engineering and Operations water temperature modelers are currently evaluating effects of different project operations on water temperatures in the LFC and HFC. Results of the modeling simulations will be used to develop specifics of how project operations could be modified to implement this Resource Action.

Implementing this Resource Action by modifying the conveyance system for water entering the Thermalito Afterbay would involve a number of complex design considerations. These are addressed in the EWG-87 narrative, which more directly addresses water temperature conditions in the Thermalito Afterbay.

The effectiveness of this measure would be evaluated by comparing water temperatures measured at several locations in the lower Feather River before and after implementing the measure. The comparisons would use water temperature modeling to adjust for differences in atmospheric conditions and other potentially confounding variables in making the comparisons. Water temperature data currently being collected in the lower Feather River will provide the information on water temperatures before implementing any changes in project operations.

Synergisms and Conflicts:
This Resource Action is compatible with Resource Actions EWG-36 and EWG-102, which share with EWG-37 the resource goal of providing desirable water temperatures for coldwater fish. By benefiting coldwater fishes, the Resource Action would likely enhance recreation in the HFC, providing increased summer angling opportunities for trout and Chinook salmon. This Resource Action would likely reduce the steep thermal gradient between the HFC and the LFC and thereby improve upstream passage and habitat conditions for anadromous salmonids, which are resource goals of many of the proposed resource actions. The colder water that would result from this measure might also help reduce predation on juvenile salmonids because the colder water would reduce metabolic rates of the fish predators in the HFC, and thereby potentially reduce their feeding rates. Reduced predation on juvenile salmonids is the resource goal for Resource Actions EWG-35A, EWG-35B and EWG- 27.

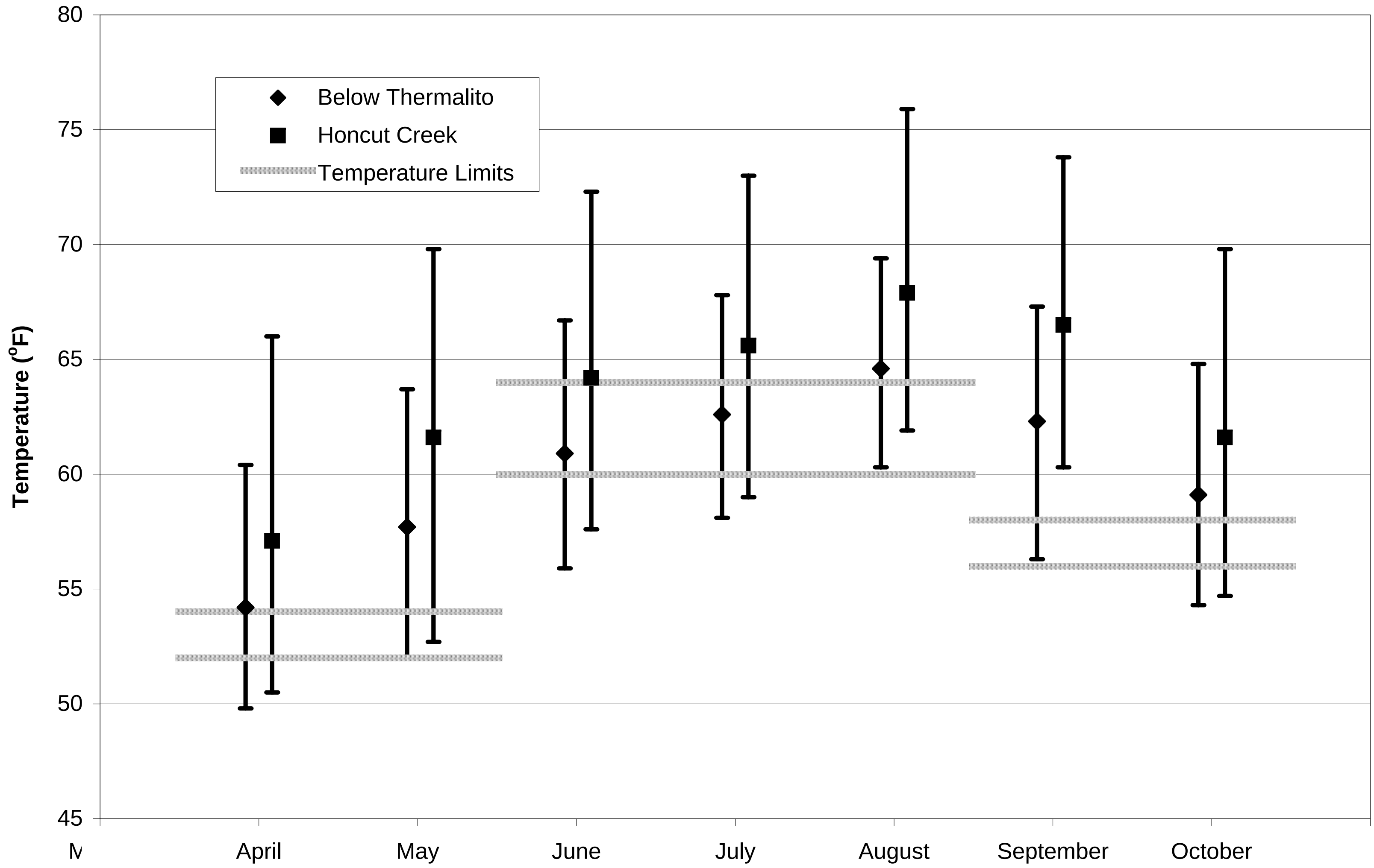
This Resource Action would potentially conflict with a number of resource goals. These include providing warmer water to Thermalito Afterbay for agriculture (e.g., EWG-87), increasing production of coldwater fishes in the reservoir, and enhancing water-contact recreational opportunities in the lower Feather River. However, to the extent that more water is diverted through the LFC rather than through the Thermalito Complex, or that the cold water entering the Thermalito Afterbay is conveyed more directly to the Thermalito Afterbay outlet, this Resource Action also has the potential to allow warmer waters for agricultural diversion from the Thermalito Afterbay (EWG-87). Depending on the methods used to reach desired water temperatures, this Resource Actioncould also have considerable costs in terms of lost power generation.

Uncertainties:
Important uncertainties related to this Resource Action include:
- Whether the amount of water in Oroville Reservoir's cold-water pool during dry and/or critically dry years would be sufficient to effect the proposed reductions in water temperatures, particularly during late summer and fall, and how a reduction in the volume of the cold-water pool would affect the cold-water fisheries of the reservoir. Whether the Resource Action could be implemented without adversely affecting salmonids in the LFC.
- Whether the Resource Action could be implemented without conflicting with DWR agreements or goals, including the FRH water temperature criteria, the agreement to accommodate water temperature needs of rice farmers, and the agreement to provide water temperatures downstream of the Thermalito Afterbay outlet from May through August that are suitable for shad, striped bass and other warmwater species.
- The amount of revenue that would be lost because of changes in power generation.

Cost Estimate:
The principle costs of this measure would be construction costs associated with modifying the conveyance system for water entering the Thermalito Afterbay and lost revenues associated with the changes in power generation (including reduced generation and changes in generation peaking). Additional costs would come from water temperature monitoring to evaluate the effectiveness of the measure and to ensure compliance with any new water temperature requirements.

Recommendations:
Before implementing this measure, better information is needed from water temperature modeling simulations. These evaluations should provide useful insights on the feasibility of the measure in light of the potential conflicts and limitations.

Figure 1. Median of Daily Average, 95th Percentile of Daily Maximum, and 5th Percentile of Daily Minimum Water Temperatures for Benchmark Study Conditions; High Flow Channel Stations



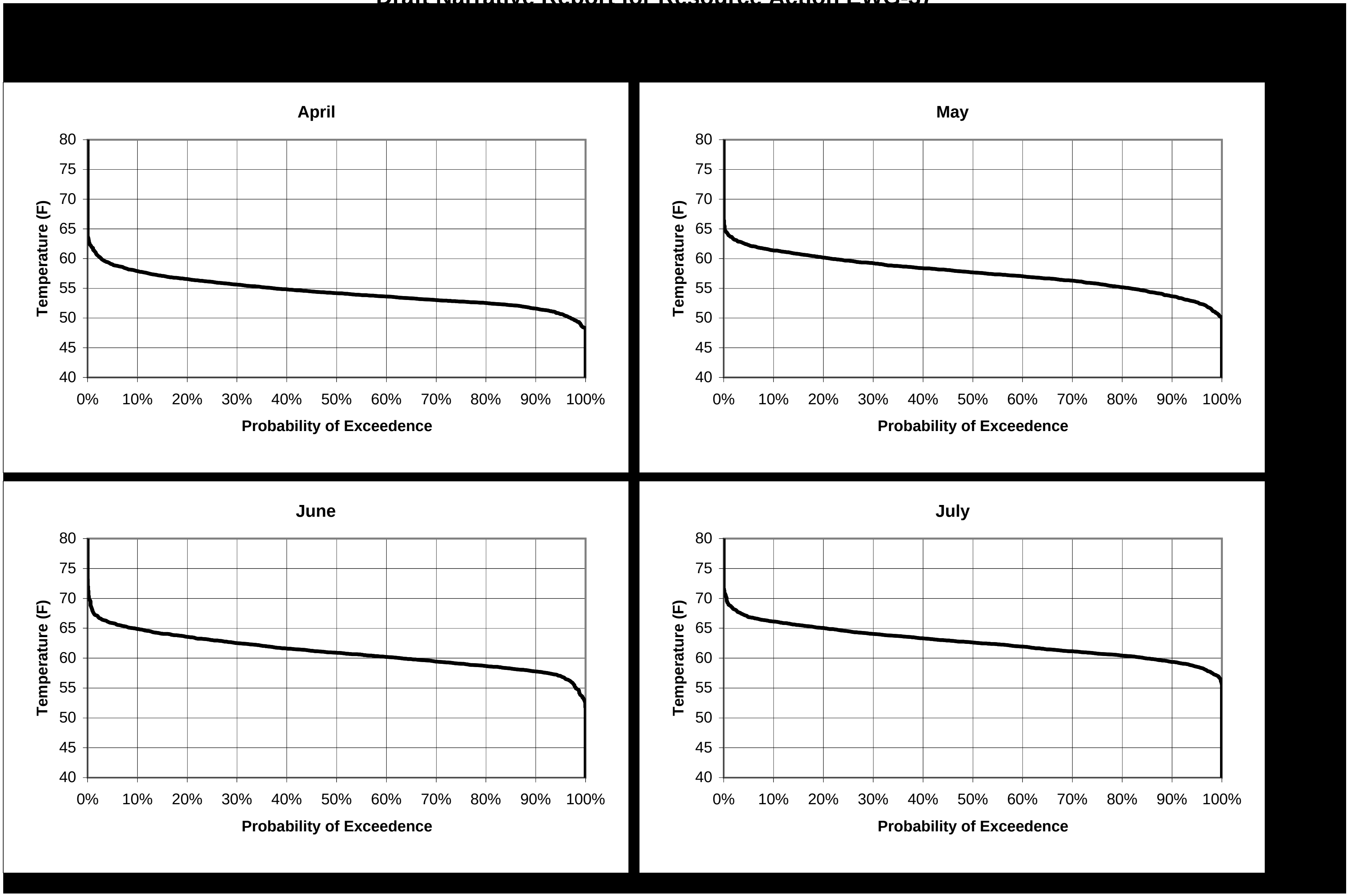
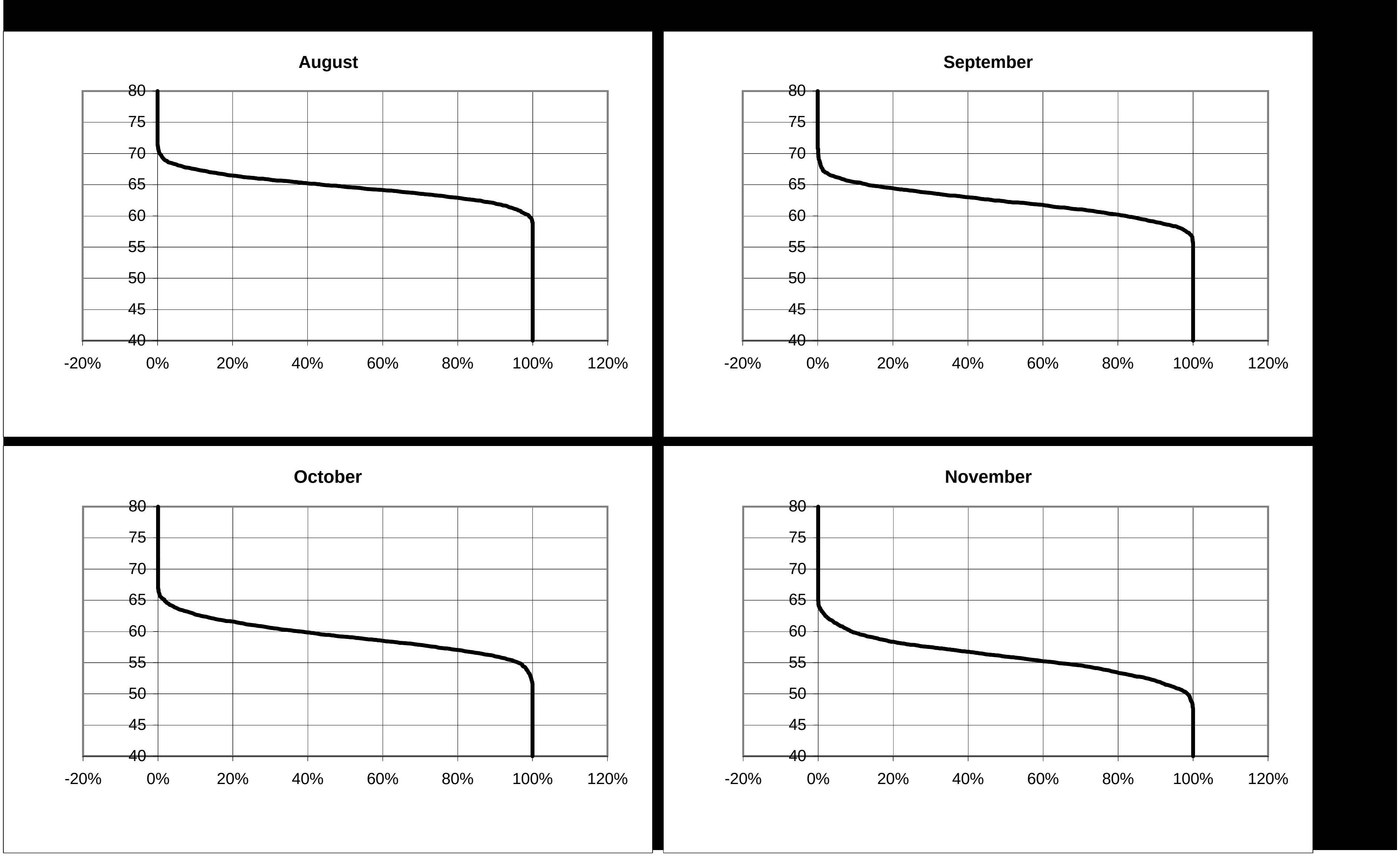


Figure 2. Daily Average Temperature Exceedence Curves for Existing Conditions Benchmark Study Results for the Feather River Below Thermalito (April-November).



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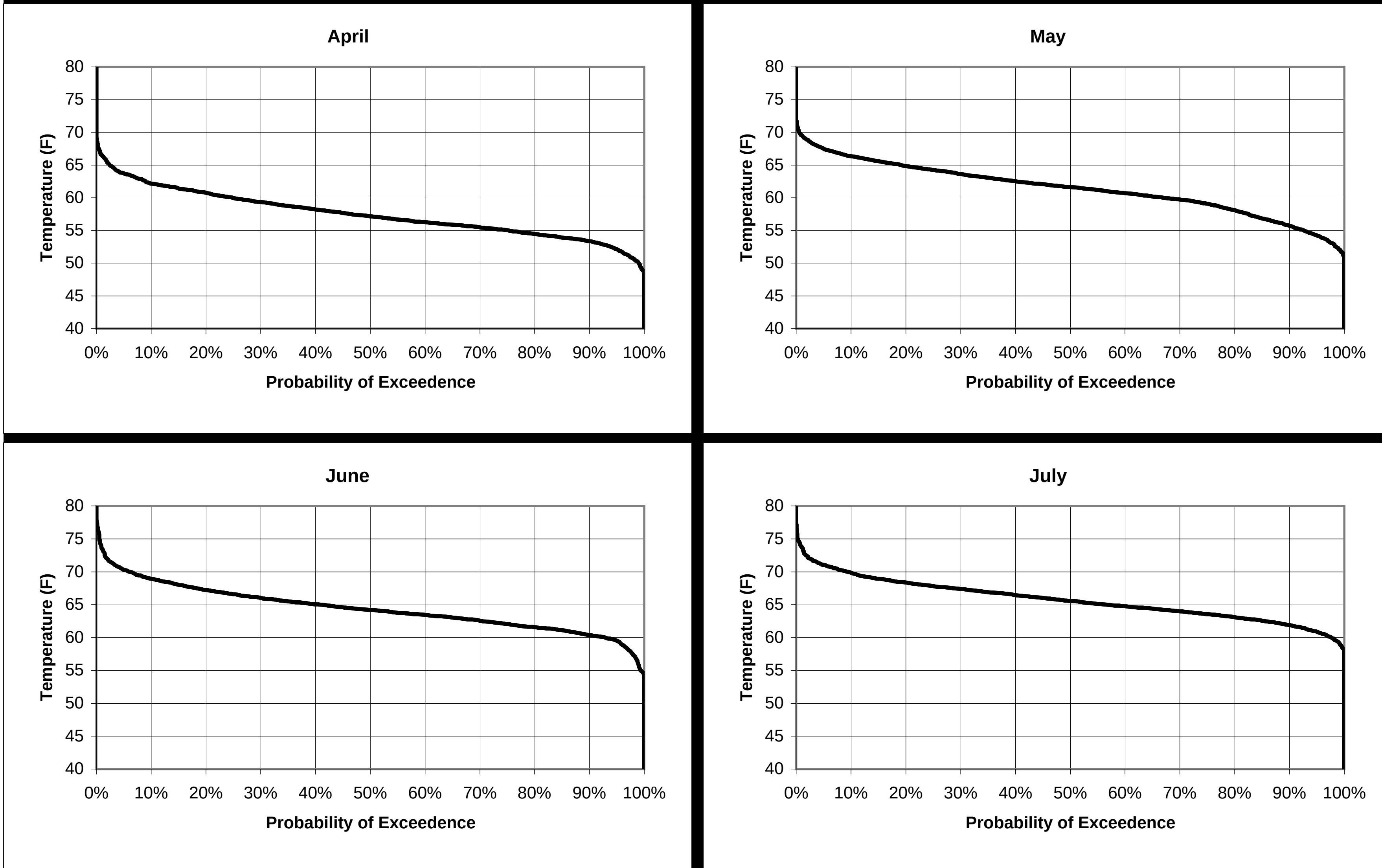

Figure 3. Daily Average Temperature Exceedence Curves for Existing Conditions Benchmark Study Results for the Feather River Above Honcut Creek (April-November).

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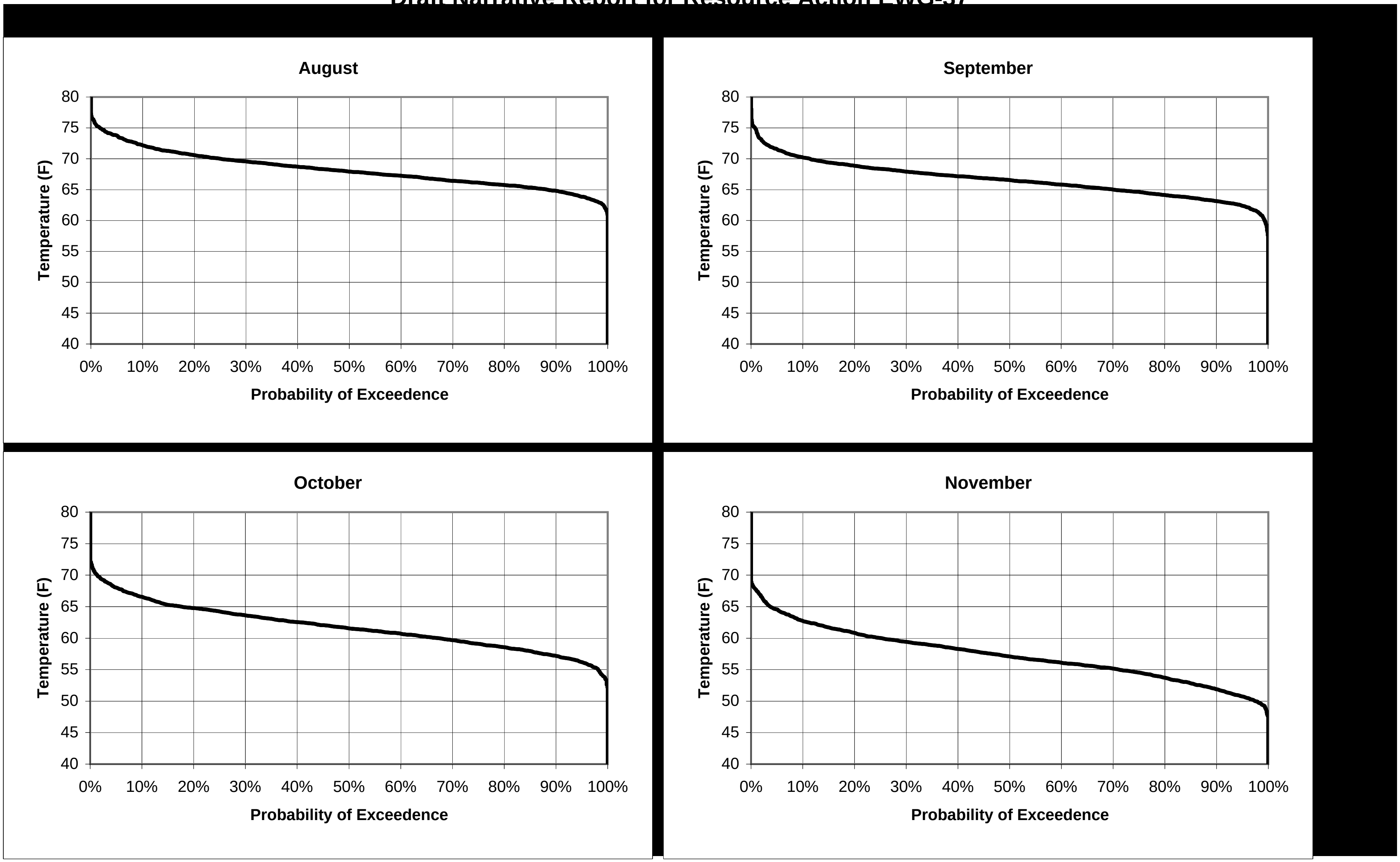

Figure 3. Daily Average Temperature Exceedence Curves for Existing Conditions Benchmark Study Results for the Feather River Above Honcut Creek (April-November).

Figure 4. Median, 95th Percentile, and 5th Percentile of Increases per River Mile in Average Daily Water Temperatures for Four Reaches in the Lower Feather River